ANNEX J

Methodology for Estimating CH_4 Emissions from Enteric Fermentation

Methane emissions from enteric fermentation were estimated for five livestock categories: cattle, horses, sheep, swine and goats. Emissions from cattle represent the majority of U.S. emissions, consequently, the more detailed IPCC Tier 2 methodology was used to estimate emissions from cattle and the IPCC Tier 1 methodology was use to estimate emissions from the other types of livestock.

Estimate Methane Emissions from Cattle

This section describes the process used to estimate methane emissions from cattle enteric fermentation. A model based on recommendations provided in IPCC/UNEP/OECD/IEA (1997) and IPCC (2000) was developed that uses information on population, energy requirements, digestible energy, and methane conversion rates to estimate methane emissions. The emission methodology consists of the following three steps: (1) characterize the cattle population to account for animal population categories with different emissions profiles; (2) characterize cattle diets to generate information needed to estimate emissions factors; and (3) estimate emissions using these data and the IPCC Tier 2 equations.

Step 1. Characterize U.S. Cattle Population

Each stage in the cattle lifecycle was modeled to simulate the cattle population from birth to slaughter. This level of detail accounts for the variability in methane emissions associated with each life stage. Given that the time in which cattle can be in a stage can be less than one year (e.g., beef calves are weaned at 7 months), the stages are modeled on a per month basis. The type of cattle use also impacts methane emissions (e.g., beef versus dairy). Consequently, cattle life stages were modeled for several categories of dairy and beef cattle. These categories are listed in Table J-1.

Table J-1: Cattle Population Categories Used for Estimating Methane Emissions

Dairy Cattle	Beef Cattle
Calves	Calves
Heifer Replacements	Heifer Replacements
Cows	Heifer and Steer Stockers
	Animals in Feedlots
	Cows
	Bulls

The key variables tracked for each of these cattle population categories (except bulls [1]) are as follows:

- *Calving rates:* The number of animals born on a monthly basis was used to initiate monthly cohorts and to determine population age structure. The number of calves born each month was obtained by multiplying annual births by the percentage of births by month. Annual birth information was taken from USDA (1999a). Average percentage of births by month for beef from USDA (USDA/APHIS/VS 1998, 1994, 1993) were used for 1990 through 1999. For dairy animals, birth rates were assumed constant throughout the year. Whether calves were born to dairy or beef cows was estimated using the dairy cow calving rate and the total dairy cow population to determine the percent of births attributable to dairy cows, with the remainder assumed to be attributable to beef cows.
- *Average weights and weight gains:* Average weights were tracked for each monthly age group using starting weight and monthly weight gain estimates. Weight gain (i.e., pounds per month) was estimated based on weight gain needed to reach a set target weight, divided by the number of months remaining

[1] Only end-of-year census population statistics and a national emission factors are used to estimate methane emissions from the bull population.

before target weight was achieved. Birth weight was assumed to be 88 pounds for both beef and dairy animals. Weaning weights were estimated to range from 480 to 575 pounds. Other reported target weights were available for 12, 15, 24, and 36 month-old animals. Live slaughter weights were derived from dressed slaughter weight data (USDA 1999f). Live slaughter weight was estimated as dressed weight divided by 0.63.

- *Feedlot placements:* Feedlot placement statistics were available that specify placement of animals from the stocker population into feedlots on a monthly basis by weight class. The model used these data to shift a sufficient number of animals from the stocker cohorts into the feedlot populations to match the reported data. After animals are placed in feedlots they progress through two steps. First, animals spend time on a step-up diet to become acclimated to the new feed type. Animals are then switched to a finishing diet for a period of time before they are slaughtered. The length of time an animal spends in a feedlot depends on the start weight (i.e., placement weight), the rate of weight gain during the start-up and finishing phase of diet, and the end weight (as determined by weights at slaughter). Weight gain during start-up diets is estimated to be 2.8 to 3 pounds per day. Weight gain during finishing diets is estimated to be 3 to 3.3 pounds per day (Johnson 1999). All animals are estimated to spend 25 days in the step-up diet phase (Johnson 1999). Length of time finishing can be calculated based on start weight, weight gain per day, and target slaughter weight.
- *Pregnancy and lactation:* Energy requirements and hence, composition of diets, level of intake, and emissions for particular animals, are greatly influenced by whether the animal is pregnant or lactating. Information is therefore needed on the percentage of all mature animals that are pregnant each month, as well as milk production, to estimate methane emissions. A weighted average percent of pregnant cows each month was estimated using information on births by month and average pregnancy term. For beef cattle, a weighted average total milk production per animal per month was estimated using information on typical lactation cycles and amounts (NRC 1999), and data on births by month. This results in a range of weighted monthly lactation estimates expressed as lbs/animal/month. The monthly estimates from January to December are 3.33, 5.06, 8.70, 12.01, 13.58, 13.32, 11.67, 9.34, 6.88, 4.45, 3.04, and 2.77. Monthly estimates for dairy cattle were taken from USDA monthly milk production statistics.
- *Death rates:* This factor is applied to all heifer and steer cohorts to account for death loss within the model on a monthly basis. The death rates are estimated by determining the death rate that results in model estimates of the end-of-year population for cows that match the published end-of-year population census statistics.
- *Number of animals per category each month:* The population of animals per category is calculated based on number of births (or graduates) into the monthly age group minus those animals that die or are slaughtered and those that graduate to next category (including feedlot placements). These monthly age groups are tracked in the enteric fermentation model to estimate emissions by animal type on a regional basis.

Table J-2 provides the cattle population estimates as output from the enteric fermentation model from 1990 through 1999. This table includes the population categories used in the model to estimate total emissions, including tracking emissions that occur the following year for feedlot animals placed late in the year. Dairy lactation estimates for 1990 through 1999 are shown in Table J-3. Table J-4 provides the target weights used to track average weights of cattle by animal type. Table J-5 provides a summary of the reported feedlot placement statistics for 1999.

Cattle population data were taken from U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) reports. The USDA publishes monthly, annual, and multi-year livestock population and production estimates. Multi-year reports include revisions to earlier published data. Cattle and calf populations, feedlot placement statistics (e.g., number of animals placed in feedlots by weight class), slaughter numbers, and lactation data were obtained from the USDA (1990-1999). Beef calf birth percentages were obtained from the National Animal Health Monitoring System (NAHMS) (USDA/APHIS/VS 1998, 1994, 1993). Estimates of the number of animals in different population categories of the model differ from the reported national population statistics. This difference is due to model output indicating the average number of animals in that category for the year rather than the end of year population census.

Step 2. Characterize U.S. Cattle Population Diets

To support development of digestible energy (DE, the percent of gross energy intake digestible to the animal) and methane conversion rate (Y_m, the fraction of gross energy converted to methane) values for each of the cattle population categories, data were collected on diets considered representative of different regions. For both grazing animals and animals being fed mixed rations, representative regional diets were estimated using information collected from state livestock specialists and from USDA (1996a). The data for each of the diets (e.g., proportions of different feed constituents, such as hay or grains) were used to determine chemical composition for use in estimating DE and Y_m for each animal type. Additional detail on the regional diet characterization is provided in EPA (2000).

DE and Y_m were used to estimate methane emissions from enteric fermentation and vary by diet and animal type. The IPCC recommends Y_m values of 3.5 to 4.5 percent for feedlot cattle and 5.5 to 6.5 percent for all other cattle. Given the availability of detailed diet information for different regions and animal types in the United States, DE and Y_m values unique to the United States[2] were developed. Table J-6 shows the regional DE, the Y_m, and percent of total U.S. cattle population in each region based on 1999 data.

DE and Y_m values were estimated for each cattle population category based on physiological modeling and expert opinion. DE and Y_m values for dairy cows and most grazing animals were estimated using a model (Donovan and Baldwin 1999) that represents physiological processes in the ruminant animals. The three major categories of input required by the model are animal description (e.g., cattle type, mature weight), animal performance (e.g., initial and final weight, age at start of period), and feed characteristics (e.g., chemical composition, habitat, grain or forage). Data used to simulate ruminant digestion is provided for a particular animal that is then used to represent a group of animals with similar characteristics. The model accounts for differing diets (i.e., grain-based, forage-based, range- based), so that Y_m values for the variable feeding characteristics within the U.S. cattle population can be estimated.

For feedlot animals, DE and Y_m values were taken from Johnson (1999). In response to peer reviewer comments (Johnson 2000), values for dairy replacement heifers are based on EPA (1993).

Step 3. Estimate Methane Emissions from Cattle

Emissions were estimated in three steps: a) determine gross energy intake using the IPCC (2000) equations, b) determine an emissions factor using the GE values and other factors, and c) sum the daily emissions for each animal type. The necessary data values include:

- Body Weight (kg)
- Weight Gain (kg/day)
- Net Energy for Activity (C_a)[3]
- Standard Reference Weight[4] (Dairy = 1,324 kg; Beef = 1,195 kg)
- Milk Production (kg/day)
- Milk Fat (percent of fat in milk = 4)
- Pregnancy (percent of population that is pregnant)
- DE (percent of gross energy intake digestible)
- Y_m (the fraction of gross energy converted to methane)

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[2] In some cases, the Y_m values used for this analysis extend beyond the range provided by the IPCC. However, EPA believes that these values are representative for the U.S. due to the research conducted to characterize the diets of U.S. cattle and to assess the Y_m values associated with different animal performance and feed characteristics in the United States.

[3] Zero for feedlot conditions, 0.17 for grazing conditions, 0.37 for high quality grazing conditions. C_a factor for dairy cows is weighted to account for the fraction of the population in the region that grazes during the year.

[4] Standard Reference Weight is used in the model to account for breed potential.

Step 3a: Gross Energy, GE:

As shown in the following equation, Gross Energy (GE) is derived based on the net energy estimates and the feed characteristics. Only variables relevant to each animal category are used (e.g., estimates for feedlot animals do not require the NE_l factor). All net energy equations are provided in IPCC (2000).

$$GE = [((NE_m + NE_{mobilized} + NE_a + NE_l + NE_p) / \{NE_{ma}/DE\}) + (NE_g / \{NE_{ga}/DE\})] / (DE / 100)$$

where,

GE =	gross energy (MJ/day)
NE_m =	net energy required by the animal for maintenance (MJ/day)
$NE_{mobilized}$ =	net energy due to weight loss (mobilized) (MJ/day)
NE_a =	net energy for animal activity (MJ/day)
NE_l =	net energy for lactation (MJ/day)
NE_p =	net energy required for pregnancy (MJ/day)
$\{NE_{ma}/DE\}$ =	ratio of net energy available in a diet for maintenance to digestible energy consumed
NE_g =	net energy needed for growth (MJ/day)
$\{NE_{ga}/DE\}$ =	ratio of net energy available for growth in a diet to digestible energy consumed
DE =	digestible energy expressed as a percentage of gross energy (percent)

Step 3b: Emission Factor

The emissions factor (DayEmit) was determined using the GE value and the methane conversion factor (Y_m) for each category. This is shown in the following equation:

$$DayEmit = [GE \times Y_m] / [55.65 \text{ MJ/kg } CH_4]$$

where,

DayEmit =	emission factor (kg CH_4/head/day)
GE =	gross energy intake (MJ/head/day)
Y_m =	methane conversion rate which is the fraction of gross energy in feed converted to methane (percent)

Emission factors were estimated for each animal type, weight and region. The implied national emission factors for each of the animal categories are outlined in Table J-7.

Step 3c: Estimate Total Emissions

Emissions were summed for each month and for each population category using the daily emission factor for a representative animal and the number of animals in the category. The following equation was used:

$$Emissions = DayEmit \times Days/Month \times SubPop$$

where,

DayEmit =	the emission factor for the subcategory (kg CH_4/head/day)
Days/Month =	the number of days in the month
SubPop =	the number of animals in the subcategory during the month

This process was repeated for each month, and the totals for each subcategory were summed to achieve an emissions estimate for the entire year. For each of the 10 subcategories of cattle listed in Table J-8. The emissions for each subcategory were then summed to estimate total emissions from beef cattle and dairy cattle for the entire year. The total emissions from 1990 through 1999 are shown in Table J-9.

Emission Estimates from Other Livestock

All livestock population data, except for horses, were taken from U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) reports. For each animal category, the USDA publishes monthly, annual, and multi-year livestock population and production estimates. Multi-year reports include revisions to earlier published data. Recent reports were obtained from the USDA Economics and Statistics System, while historical data were downloaded from the USDA-NASS. The Food and Agriculture Organization (FAO) publishes horse population data. These data were accessed from the FAOSTAT database at http://apps.fao.org/. Methane emissions from sheep, goats, swine, and horses were estimated by multiplying published national population estimates by the national emission factor for each year. Table J-10 shows the populations used for these other livestock from 1990 to 1999 and Table J-11 shows the emission factors used for these other livestock.

A complete time series of enteric fermentation emissions from livestock is shown in Table J-12 (Tg CO_2 Eq.) and Table J-13 (Gg).

Table J-2: Estimates of Average Annual Populations of U.S. Cattle 1990-1999 (Thousand Head)

Livestock Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Calves 0-6 months	22,561	22,531	22,707	23,004	23,346	23,468	23,255	22,810	22,557	22,594
Dairy										
Cows	10,015	9,965	9,728	9,658	9,528	9,487	9,416	9,309	9,191	9,133
Replacements 7-11 months	1,214	1,219	1,232	1,230	1,228	1,220	1,205	1,182	1,192	1,176
Replacements 12-23 months	2,915	2,874	2,901	2,926	2,907	2,905	2,877	2,838	2,797	2,839
Beef										
Cows	32,454	32,520	33,007	33,365	34,650	35,156	35,228	34,271	33,683	33,745
Replacements 7-11 months	1,269	1,315	1,402	1,465	1,529	1,492	1,462	1,378	1,322	1,306
Replacements 12-23 months	2,967	3,063	3,182	3,393	3,592	3,647	3,526	3,391	3,212	3,106
Steer Stockers	8,639	8,215	9,303	9,066	10,378	10,126	9,457	9,008	8,703	8,276
Heifer Stockers	5,103	4,903	5,143	4,971	5,846	5,729	5,451	5,560	5,365	5,218
Total Adjusted Feedlot[a]	10,494	10,368	10,339	9,840	10,660	11,252	11,289	11,460	11,449	12,881
Bulls	2,160	2,196	2,239	2,278	2,312	2,385	2,384	2,350	2,270	2,281
Total Placements[b,c]	25,587	25,396	25,348	25,586	26,615	27,623	27,580	28,560	27,149	29,812

Source: Enteric Fermentation Model.

[a] Total Adjusted Feedlot = Average number in feedlots accounting for current year plus the population carried over from the previous year (e.g., the "next year" population numbers from this table are added into the following years "adjusted numbers").

[b] Placements represent a flow of animals from backgrounding situations to feedlots rather than an average annual population estimate.

[c] Reported placements from USDA are adjusted using a scaling factor based on the slaughter to placement ratio.

Table J-3: Dairy Lactation by Region (lbs· year/cow)*

Year	California	West	Northern Great Plains	Southcentral	Northeast	Midwest	Southeast
1990	18,800	16,769	13,502	12,397	14,058	14,218	12,943
1991	18,771	16,631	13,316	12,389	14,560	14,555	12,850
1992	19,072	17,838	13,597	12,710	15,135	15,028	13,292
1993	18,852	17,347	14,109	13,034	14,937	15,203	13,873
1994	20,203	17,890	14,496	13,236	15,024	15,374	14,200
1995	19,573	17,724	14,650	13,228	15,398	15,728	14,384
1996	19,161	18,116	14,872	13,215	15,454	15,596	14,244
1997	19,829	18,248	15,013	13,212	15,928	16,027	14,548
1998	19,442	18,377	15,489	13,580	16,305	16,494	14,525
1999	20,788	19,330	15,910	13,476	16,571	16,655	14,930

Source: USDA (2000d).

* Beef lactation data were developed using the methodology described in the text.

Table J-4: Target Weights for Use in Estimating Average Weights and Weight Gains (lbs)

Cattle Type	Typical Weights
Beef Replacement Heifer Data	
Replacement Weight at 15 months	715
Replacement Weight at 24 months	1,078
Mature Weight at 36 months	1,172
Dairy Replacement Heifer Data	
Replacement Weight at 15 months	800
Replacement Weight at 24 months	1,225
Mature Weight at 36 months	1,350
Stockers Data – Grazing/Forage Based Only	
Steer Weight Gain/Month to 12 months	45
Steer Weight Gain/Month to 24 months	35
Heifer Weight Gain/Month to 12 months	35
Heifer Weight Gain/Month to 24 months	30

Source: Feedstuffs (1998), Western Dairyman (1998), Johnson (1999), NRC (1999).

Table J-5: Feedlot Placements in the United States for 1999* (Number of animals placed in Thousand Head)

Weight When Placed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
< 600 lbs	379	333	357	293	290	295	333	494	629	1,027	766	465	5,661
600 - 700 lbs	628	497	468	387	430	377	400	486	557	802	657	498	6,187
700 - 800 lbs	604	606	744	572	722	634	578	734	758	692	416	422	7,482
> 800 lbs	322	372	462	436	607	488	501	714	815	593	331	261	5,902
Total	**1,933**	**1,808**	**2,031**	**1,688**	**2,049**	**1,794**	**1,812**	**2,428**	**2,759**	**3,114**	**2,170**	**1,646**	**25,232**

Source: USDA (1999b).

Note: Totals may not sum due to independent rounding.

* Data were available for 1996 through 1999. Data for 1990 to 1995 were based on the average of monthly placements from the 1996 to 1998 reported figures.

Table J-6: Regional Digestible Energy (DE), Methane Conversion Rates (Y_m), and population percentages for Cattle in 1999

Animal Type	Data	California	West	Northern Great Plains	Southcentral	Northeast	Midwest	Southeast
Beef Repl. Heif.[a]	DE[b]	67	66	68	66	64	68	68
	Y_m[c]	8.0%	7.4%	8.0%	8.3%	8.4%	8.0%	7.8%
	Pop.[d]	3%	11%	28%	25%	4%	13%	17%
Dairy Repl. Heif.[a]	DE	66	66	66	64	68	66	66
	Y_m	5.9%	5.9%	5.6%	6.4%	6.3%	5.6%	6.9%
	Pop.	18%	18%	4%	4%	19%	31%	5%
Steer Stockers[a]	DE	67	66	68	66	64	68	68
	Y_m	8.0%	7.4%	8.0%	8.3%	8.4%	8.0%	7.8%
	Pop.	4%	10%	38%	22%	2%	16%	7%
Heifer Stockers[a]	DE	67	66	68	66	64	68	68
	Y_m	8.0%	7.4%	8.0%	8.3%	8.4%	8.0%	7.8%
	Pop.	0%	8%	45%	23%	2%	13%	8%
Steer Feedlot[e]	DE	85	85	85	85	85	85	85
	Y_m	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
	Pop.	3%	7%	47%	24%	1%	17%	1%
Heifer Feedlot[e]	DE	85	85	85	85	85	85	85
	Y_m	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
	Pop.	3%	7%	47%	24%	1%	17%	1%
Beef Cows[a]	DE	67	66	68	66	64	68	68
	Y_m	8.0%	7.4%	8.0%	8.3%	8.4%	8.0%	7.8%
	Pop.	2%	8%	28%	26%	2%	14%	19%
Dairy Cows[e]	DE	69	66	69	68	69	69	68
	Y_m	4.8%	5.8%	5.8%	5.7%	5.8%	5.8%	5.6%
	Pop.	16%	10%	5%	6%	21%	34%	8%
Steer Step-Up[e,f]	DE	76	76	76	76	76	76	76
	Y_m	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%
Heifer Step-Up[e]	DE	76	76	76	76	76	76	76
	Y_m	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%

[a] Beef and Dairy grazing DE and Y_m values were applied to all grazing beef animals. It was assumed that pasture quality remains relatively consistent at a regional scale.

[b] Digestible Energy in units of percent GE (MJ/Day).

[c] Methane Conversion Rate is the fraction of GE in feed converted to methane.

[d] Estimated percent of each subcategory population present in each region.

[e] DE and Y_m values for 1990 through 1992 are values from the previous livestock characterization reported in the 1993 Report to Congress. Values for 1993 through 1995 are the mean of current values and the 1993 Report to Congress values. Values for 1996 through 1999 are values from the most recent livestock characterization.

[f] Characteristics of heifer and steer step-up diets (i.e., diets fed to animals entering feedlots) were assessed nationally to account for the difference between initial and finishing diets for feedlot animals.

Table J-7: Implied Emission Factors for Cattle in the United States (kg CH_4/head/yr)

Animal Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Calves 0-6 months	0	0	0	0	0	0	0	0	0	0
Dairy										
Cows	113	114	117	111	113	113	107	109	110	111
Replacements 7-11 months	40	40	40	40	40	40	40	40	40	40
Replacements 12-23 months	63	63	63	63	63	63	63	63	63	63
Beef										
Cows	83	83	83	83	83	83	83	83	83	82
Replacements 7-11 months	47	47	47	47	47	47	47	47	48	47
Replacements 12-23 months	73	73	73	73	73	73	73	73	74	74
Steer Stockers	64	64	64	64	64	64	64	64	64	64
Heifer Stockers	56	56	57	57	58	57	57	57	57	57
Total Feedlot	47	47	47	40	39	39	34	33	34	33
Bulls	100	100	100	100	100	100	100	100	100	100

"0" = assumed to be zero.
Source: Enteric Fermentation Model.

Table J-8: CH_4 Emissions from Cattle (Gg)

Cattle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy	**1,369**	**1,370**	**1,368**	**1,307**	**1,307**	**1,308**	**1,241**	**1,240**	**1,234**	**1,245**
Cows	1,136	1,140	1,135	1,073	1,074	1,076	1,010	1,013	1,010	1,018
Replacements 7-11months	49	49	49	49	49	49	48	48	48	47
Replacements 12-23 months	184	181	183	185	184	184	182	179	177	180
Beef	**4,511**	**4,485**	**4,628**	**4,565**	**4,851**	**4,902**	**4,781**	**4,658**	**4,561**	**4,544**
Cows	2,682	2,687	2,728	2,758	2,865	2,907	2,912	2,832	2,784	2,777
Replacements 7-11 months	59	62	66	69	72	70	68	65	63	62
Replacements 12-23 months	217	224	233	248	263	267	258	248	239	230
Steer Stockers	553	527	598	584	669	653	606	577	557	527
Heifer Stockers	288	276	292	283	337	329	311	319	307	297
Feedlot Cattle	496	490	488	395	415	438	387	383	385	423
Bulls	216	220	224	228	231	238	238	235	227	228
Total	**5,880**	**5,855**	**5,996**	**5,872**	**6,158**	**6,211**	**6,022**	**5,897**	**5,796**	**5,789**

Note: Totals may not sum due to independent rounding.

Table J-9: Cattle Emissions (Tg CO_2 Eq.)

Cattle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Dairy	28.7	28.8	28.7	27.4	27.4	27.5	26.1	26.0	25.9	26.1
Beef	94.7	94.2	97.2	95.9	101.9	103.0	100.4	97.8	95.8	95.4
Total	**123.5**	**123.0**	**125.9**	**123.3**	**129.3**	**130.4**	**126.5**	**123.8**	**121.7**	**121.6**

Note: Totals may not sum due to independent rounding.

Table J-10: Other Livestock Populations 1990-1999 (Thousand Head)

Livestock Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Sheep	11,358	11,174	10,797	10,201	9,825	8,982	8,458	8,015	7,817	7,215
Goats	2,545	2,475	2,645	2,605	2,605	2,495	2,545	2,295	2,045	1,995
Horses	5,650	5,650	5,850	5,900	6,000	6,000	6,050	6,150	6,150	6,180
Swine	53,941	56,478	58,532	58,016	59,951	58,899	56,220	58,728	62,043	59,407

Source: USDA (2000b,e 1999d-e,h, 1998, b-c, 1994a-b), FAO (2000).

Table J-11: Emission Factors for Other Livestock (kg CH_4/head/year)

Livestock Type	Emission Factor
Sheep	8
Goats	5
Horses	18
Swine	1.5

See Table J-7 for emissions factors for cattle.
Source: IPCC (2000).

Table J-12: CH_4 Emissions from Enteric Fermentation (Tg CO_2 Eq.)

Livestock Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beef Cattle	94.7	94.2	97.2	95.9	101.9	103.0	100.4	97.8	95.8	95.4
Dairy Cattle	28.7	28.8	28.7	27.4	27.4	27.5	26.1	26.0	25.9	26.1
Horses	2.1	2.1	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3
Sheep	1.9	1.9	1.8	1.7	1.7	1.5	1.4	1.3	1.3	1.2
Swine	1.7	1.8	1.8	1.8	1. 9	1.9	1.8	1.8	2.0	1.9
Goats	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2
Total	**129.5**	**129.0**	**132.1**	**129.4**	**135.4**	**136.3**	**132.2**	**129.6**	**127.5**	**127.2**

Table J-13: CH_4 Emissions from Enteric Fermentation (Gg)

Livestock Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Beef Cattle	4,511	4,485	4,628	4,565	4,851	4,902	4,781	4,658	4,561	4,544
Dairy Cattle	1,369	1,370	1,368	1,307	1,307	1,308	1,241	1,240	1,234	1,245
Horses	102	102	105	106	108	108	109	111	111	111
Sheep	91	89	86	82	79	72	68	64	63	58
Swine	81	85	88	87	90	88	84	88	93	89
Goats	13	12	13	13	13	12	13	11	10	10
Total	**6,166**	**6,143**	**6,289**	**6,160**	**6,447**	**6,492**	**6,295**	**6,172**	**6,072**	**6,057**